bidder with the highest willingness to pay may not submit the highest bid.[46]

In addition, the Commission's proposed auction sequence may lead to further inefficiencies. For example, if combinatory bids are not opened until after all the individual auctions are completed, many bidders who submitted combinatory bids may refrain from participating in the individual auctions or may participate less aggressively than they otherwise would have due to their reluctance to "bid against" their previously submitted, but as-yet undisclosed, combinatory bids. Seen in this light, the Commission's auction sequence could result in the awarding of many individual licenses to bidders who did not value them most, contrary to the Commission's guiding principle.[47]

The Commission posits a "best and final" mechanism as a "possible refinement" to its basic auction sequence, apparently to improve the likelihood of assigning licenses to the eligible parties valuing them most and of obtaining maximum value revelation.[48] Notwithstanding the commendable objectives of the proposal to use a "best and final" mechanism, however, the incentives created by such a process are potentially dramatically different. As Dr. Isaac describes it:

> [The individual bidders in the "best and final" round] do not face a standard bidding problem because they are not bidding only to keep their one license. Instead,

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46 OPP Spectrum Auction Study at 23.

47 Notice at ¶ 34.

48 Id. at ¶ 60.

> these bidders, as a group, face a public goods "assurance" problem, with the standard incentives to try to let the other pay for the good.... By itself, this suggests a strong possibility that the "final and best" round would be a non starter.[49]

The free rider problem here is quite real, as CTIA's members can attest. For example, in the market exchanges for cellular licenses which occurred in the mid-1980's under FCC auspices post-lotteries, substantial inefficiencies were threatened by exploitation of free rider opportunities.

By contrast, CTIA's alternative auction sequence will itself implement the Commission's assignment-to-the-highest-value principle and more closely obtain maximum demand revelation while avoiding the free rider problem created by the "best and final" mechanism. By posting the winning combinatory bid prior to conducting individual auctions, the Commission will encourage those bidders who submitted combinatory bids but lost to participate in the individual auctions. Moreover, because these bidders will have been relieved of the fear of bidding against themselves (by virtue of the posting of the winning combinatory bid), their bidding at the individual license level will more closely approximate their maximum willingness to pay for individual licenses.

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[49] Isaac at 13 (emphasis in original) (citations omitted). Dr. Isaac also points out that allowing communication among the individual bidders in the "best and final" round in an attempt to avoid the free rider problem would likely provide the government with little additional revenue, because the individual license winners would seek to exceed the sealed bid by the absolute minimum amount. Id. at 14.

Thus, under CTIA's auction sequence, the maximization of revenues and efficient auction design coincide. Accordingly, CTIA respectfully urges the Commission to adopt this modified approach.

2. All Geographic Regions Should be Offered Sequentially Within a Given Spectrum Block Before Proceeding to Auction the Next Spectrum Block

The Commission is correct in noting that if bidding is done sequentially, "the order in which items are offered can affect the outcome."[50] Moreover, CTIA agrees with the Commission's stated objective of "establish[ing] the sequence of bidding that is most likely to facilitate economically efficient aggregation of licenses across geographic regions and spectrum blocks while complying with the statute."[51]

In the context of the PCS Order, the sequence of bidding required to achieve this objective is the auctioning of all geographic regions within a given spectrum block before proceeding to auction the next spectrum block. This bidding sequence is preferable with respect to PCS because 10 MHz appears sufficient to achieve the minimum efficient scale of PCS operation, and PCS aggregation across geographical areas is likely to be more important than aggregation across spectrum blocks.[52] The Commission expressly recognized the sufficiency of

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[50] See Notice at ¶ 52.

[51] Id.

[52] Id.

a 10 MHz allocation for viable PCS operation in its recent PCS Order:

> We conclude that a 10 MHz allocation can support viable and competitive PCS services through the use of digital methods such as CDMA and TDMA and microcellular technology....[53]

Accordingly, auctioning of PCS licenses should proceed as follows: The Commission should first accept combinatory bids for the "A" block, open the bids and post the winning combinatory bid publicly, and then proceed to auction each of the constituent licenses individually. This same sequence would then be repeated for the "B" block, and thereafter for blocks "C" through "G."[54]

3. Within a Given Spectrum Block, Geographic Regions Should Be Licensed In Descending Order of Population

CTIA agrees that within each PCS spectrum block, the Commission should auction geographic areas in descending order of population.[55] This bidding sequence would allow auction winners of licenses for large cities to seek to achieve economies of scale and scope by clustering smaller markets around a larger market "hub." For example, a firm that wishes to establish a

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[53] PCS Second Report and Order, Gen. Docket No. 90-314, FCC 93-451 (released October 22, 1993) at ¶ 57.

[54] If, on reconsideration, the Commission adopts a different spectrum allocation/service area scheme, the same auction sequence would still apply. The larger geographic area within each spectrum block would be auctioned first using a sealed, combinatory bid. The winning combinatory bid would then be posted, at which point bidding on the smaller constituent geographic areas would commence using English auctions. See n. 9, supra.

[55] See Notice at ¶ 125.

regional PCS network surrounding a large city would not know how much to bid in the first round of the auction if the large city were not auctioned until later because the firm would be unsure how much it would cost to acquire this "hub" in the later round. As a result of this uncertainty, it is possible that the smaller surrounding geographic markets auctioned in the earlier rounds may not be assigned to the party that values them most.[56] By auctioning markets in each spectrum block in descending order of population, the Commission thus facilitates an economical and efficient business strategy, while also furthering its objective of awarding licenses to the eligible parties who value them most.

II. AUCTION APPLICATION PROCEDURES

A. The Proposed Pre-Auction Application Procedures Must be Simplified to Foster Widespread Bidder Participation

The Commission proposes an array of rigorous pre-auction application requirements and procedures that are wholly unnecessary in the competitive bidding context. For example, the Commission proposes to (1) require the submission of both a short-form and long-form application prior to the auction;[57] (2) judge the short-form application by a "letter-perfect" standard;[58] and (3) attempt to distinguish between major and

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[56] See OPP Spectrum Auction Study at 23-24.

[57] Notice at ¶ 97.

[58] Id. at ¶ 100, n. 185.

minor modifications to short-form applications prior to the auction.[59]

Each of these proposals is rooted in old notions of comparative hearings and lotteries in which rigorous pre-screening of the applicant pool was arguably necessary.[60] The introduction of competitive bidding fundamentally alters the dynamics of the licensing process, such that these procedural hurdles, and the extensive costs incurred to administer and enforce them, are rendered unnecessary.[61] With auctions, the Commission's goal should be to encourage widespread bidding participation,[62] rather than exclude bidders for minor errors.[63]

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[59] Id. at ¶ 101. With respect to PCS, the Notice proposes that no modifications of any kind be permitted until after a winning bidder has emerged. See id. at 129.

[60] In the past, the Commission attempted to raise procedural hurdles to dampen speculation and limit participation to parties with an intention of providing service.

[61] See Dingell Letter at 4 ("[T]he competitive bidding statute has altered fundamentally the way in which the Commission approaches allocation decisions").

[62] Toward this end of maximizing participation, CTIA urges the Commission to allow all bidders, not just the designated parties identified in Section 309(j)(4)(D), to be entitled to purchase spectrum using installment payments with interest set at the prime rate plus one percent. The House Report envisioned a wide variety of payment techniques to encourage such widespread participation, House Report at 255, and permitting all parties to use periodic payments could reduce concerns about "deep pockets." See "U.S. Spectrum Management Policy: Agenda for the Future," NTIA Special Publication 91-23 (February 1991) at 117 ("[P]eriodic payments, whether "lease payments" or royalties, could reduce concerns about "deep pockets," since bidders would compete largely on the basis of future payments, which would be due only after they had access to the spectrum to produce revenues").

(continued...)

Of course, the Commission is correct in asserting that its rules should deter frivolous bids and minimize the probability that, after the auction is over, the Commission finds that it cannot award a license to a winner.[64] However, the proposed pre-auction procedures are more likely to eliminate qualified bidders inadvertently than deter frivolous applications. While the Act requires auction applicants to submit such "information and assurances as the Commission may require to demonstrate that such bidder's application is acceptable for filing,"[65] it does not mandate strict bidder qualification requirements that would have such unintended effects.[66]

Further, strict procedural requirements are unwarranted in light of the Commission's proposal to retain the deposit of

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[62](...continued)
CTIA recommends that the Commission not allow royalty payments, however, since there is no easily administrable way to measure output of the spectrum licensee on which to base the royalties. See Notice at ¶ 70.

[63] See, e.g., Northeast Cellular Telephone Company, L.P. v. F.C.C., 897 F.2d 1164 (D.C. Cir. 1990) (court overturned FCC waiver of cellular applicant's strict compliance with FCC's financial qualification rules, notwithstanding a Commission finding that strict compliance with these rules was unnecessary given the FCC's lengthy experience with the tentative lottery selectee's financial backers (i.e., NYNEX Mobile) and the fact that strict compliance would not serve the public interest and would only result in needless delay).

[64] Notice at ¶ 102.

[65] 47 U.S.C. § 309(5).

[66] In fact, the House Report notes that Commission discretion to evaluate bidder qualifications is strictly limited to the winning applicant. All other applicants need only meet "minimum requirements of acceptability." House Report at 258.

winning bidders who are ultimately found to be unqualified or ineligible or who are unable to pay the balance of their bids.[67] As CTIA discusses in Section II.B, infra, this deposit-forfeiture rule is well within the Commission's authority under the Act and is all that is needed to deter frivolous or unqualified applications.

Accordingly, CTIA recommends that the Commission minimize pre-auction requirements. Applicants should be required to file only a short-form application prior to the auction.[68] The sole purpose of this short-form should be to discern whether mutual exclusivity exists,[69] and should thus be correspondingly short and liberally judged. Qualification assessments, verification of compliance with substantive Commission rules, and any petitions to deny should be undertaken only with respect to auction winners. In addition to maximizing bidder participation consistent with the Act, this approach would avoid the procedural

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[67] Notice at ¶ 109.

[68] There is no reason to require all bidders to file a long-form application before the auction. Especially since the Commission will not be reviewing these applications pre-auction, it should avoid the substantial administrative burden which the processing and storing of these applications would entail. See Notice at n. 179 (Commission questions whether, in light of the anticipated storage burden, pre-auction long-form applications should be filed on microfiche).

[69] See id. at n. 91, ¶ 171.

quagmires and attendant delays invited by a more rigorous "letter-perfect" standard.[70]

B. The Commission Should Retain the Deposit of an Auction Winner Who is Unqualified, Ineligible, or Unable to Pay Its Bid

The most effective way to deter frivolous or ill-considered applications is for the Commission to retain the auction winner's deposit in the event the winner is ultimately found to be unqualified, ineligible, or is unable to pay the balance of its bid.[71] This potential forfeiture, when combined with the streamlined pre-auction procedures described above, will maximize participation of serious bidders.[72]

The Commission is well within its authority to retain deposits. As the Commission correctly notes, this forfeiture rule effectively implements the Commission's simplicity principle, as well as the Act's overriding goals of promoting "efficient and intensive use of the electromagnetic spectrum" and "investment in and rapid deployment of new technologies and

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[70] For example, the petitions for reconsideration and petitions for review filed by parties whose pre-auction applications are denied under the letter-perfect standard would serve only to delay PCS implementation without producing any benefits. This situation would be exacerbated by the Commission's proposal to allow conditional participation in the auction and conditional assignment of licenses to these parties, pending the ultimate outcome of their appeals. See Notice at ¶ 185.

[71] See Notice at ¶¶ 102, 109, 113, 174-175.

[72] A substantial upfront deposit will also deter participation in the auction process solely for the purpose of extorting "greenmail" from legitimate applicants. See discussion at Section III, infra.

services."[73] Moreover, this rule is consistent with Congress' directive to include penalty provisions in the Commission's regulations for failure to meet performance requirements[74] and to "deter speculation and participation in the licensing process by those who have no intention of offering service to the public."[75]

Of course, to be a successful deterrent, the formula for calculating deposits must yield a sizeable sum. CTIA supports the Commission's proposed formula for calculating the upfront payment,[76] as well as its proposal to have the winning bidder tender promptly the difference, if any, between the upfront payment and 20% of the winning bid.[77] Finally, to ensure participation by only serious, qualified bidders in auctions for "narrowband" channels in small markets where the Commission's formula yields an insufficient upfront payment, CTIA recommends that the Commission adopt a minimum upfront payment of $5,000.

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[73] Id. at ¶ 109.

[74] 47 U.S.C. § 309(j)(4)(B). See also House Report at 256. In this sense, the Commission's retention of the deposit is no different from its past practice of using penalties, including license forfeiture, as a means of ensuring that licensees build out their systems. See House Report at 256.

[75] House Report at 257. See also 47 U.S.C. § 309(j)(4)(E).

[76] See Notice at ¶ 103.

[77] Id. at ¶ 104.

III. TO AVOID GREENMAIL EXTORTION IN THE AUCTIONING OF INTERMEDIATE MICROWAVE LINKS, THE COMMISSION SHOULD: (1) ALLOW THE CONTINUED USE OF "STAS" AND "TFAS" FOR THE PRE-AUTHORIZATION CONSTRUCTION AND OPERATION OF THESE LINKS AND (2) ADOPT AN EXPEDITED SCHEDULE FOR AUCTIONING THESE LINKS

CTIA agrees with the Commission that intermediate microwave links should be subject to competitive bidding.[78] In response to the Notice's inquiry at ¶ 29, CTIA notes that the number of situations where mutual exclusivity[79] will arise with respect to point-to-point microwave licenses used as intermediate or "backhaul" links within a cellular system will likely be very small. However, while mutual exclusivity may arise infrequently in this context, greenmail extortion -- whereby a speculator with no interest in using the intermediate link attempts to exact money from legitimate applicants in return for a promise not to delay the licensing process -- may be a much more common occurrence. To minimize the potential for greenmail extortion, the Commission should (1) allow applicants to continue to use "Special Temporary Authorizations" and "Temporary-Fixed Authorizations" to construct and operate intermediate microwave

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[78] Id. at ¶¶ 28-29. CTIA also concurs that cellular unserved area applications filed prior to July 26, 1993 should be licensed via auctions. See id. at ¶ 160.

[79] Although the Notice does not expressly define it, "mutual exclusivity" exists only where there are multiple applicants for a single license. See House Report at 253 ("Competitive bidding would not be permitted to be used ... in situations where there is only one application for a license...."); OPP Spectrum Auction Study at 2 ("If more than one party applies for a given exclusive channel, these applications are said to be mutually exclusive."). See also Notice at ¶¶ 130, 171, n. 91.

links at their own risk prior to the grant of a permanent authorization and (2) adopt an extremely expedited schedule, i.e., seven days after the statutory 30-day notice period, for auctioning intermediate links.

Fixed microwave applicants may now construct and operate facilities prior to the grant of a permanent authorization by requesting Special Temporary Authorizations ("STAs") where the applicant can show that there are extraordinary circumstances requiring operation in the public interest and that delay would seriously prejudice the public interest.[80] In addition, the Commission's rules accommodate applicants whose need for fixed microwave service is sufficiently limited (i.e., less than six months, but renewable) through the use of "Temporary-Fixed Authorizations" ("TFAs").[81] More recently, cellular licensees have been permitted to use "blanket STAs" to construct and operate intermediate microwave links within their systems prior to the licensing process, as long as prior frequency coordination has been completed. In these instances, cellular licensees have assumed the risk that their applications would not ultimately be

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[80] 47 U.S.C. § 309(f); 47 C.F.R. § 21.25.

[81] 47 U.S.C. § 309(f); 47 C.F.R. §§ 21.707 and 21.708. Under 47 C.F.R. §§ 21.707-708, fixed microwave applicants may commence construction and operation for a period of less than six months upon at least five days' notice to the Commission provided that prior frequency coordination is completed and that certain other conditions are met.

granted, or that the Commission would order the proposed facilities altered, relocated, or dismantled.[82]

CTIA urges the Commission to allow fixed-microwave applicants to continue to use these STAs and TFAs under the competitive bidding licensing process. The use of these streamlined procedures for pre-authorization construction and operation of intermediate microwave links will effectively insulate prospective licensees from greenmail extortion, while also permitting fixed microwave applicants to respond more efficiently to increased demands for rapid delivery of service and promoting more efficient spectrum use consistent with overriding Congressional and Commission objectives and with the public interest.[83]

Finally, as an additional deterrent to greenmail extortion, the Commission should establish an expedited schedule for auctioning intermediate microwave links. License applications for this service should be placed on public notice for the statutory 30 days. Any mutually exclusive application filed

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[82] Additionally, the Commission has proposed to revise Part 21 of its rules to remove the requirement that all Point-to-Point Microwave Radio Service ("PPMS") applicants receive an authorization prior to the construction of facilities. See Amendment of Part 21 of the Commission's Rules for the Domestic Public Fixed Radio Services, 8 FCC Rcd. 1112 (1993). CTIA filed comments in this proceeding in support of the Commission's proposal and urged the Commission to take the further step of adopting rules that permit all PPMS applicants to commence operation prior to receipt of authorization. CTIA Reply Comments, filed in CC Docket No. 93-2, April 16, 1993.

[83] Of course, a fixed microwave applicant would still assume the risk that it may ultimately lose the spectrum auction for the license or that its application may ultimately be denied.

within that 30-day period should trigger an auction being scheduled within one-week's time frame for that license. By implementing such an expedited schedule, the Commission will effectively defuse the greenmail extortionist's threat to delay the licensing process, and ensure that only those applicants genuinely interested in utilizing the frequency are awarded the license.

CONCLUSION

Based on the foregoing, CTIA respectfully urges the Commission to adopt CTIA's modified auction design and to implement streamlined procedures to maximize bidder participation in spectrum auctions. This approach will best achieve the Spectrum Auction Act's overriding goals of development and rapid deployment of new technologies, products, and services; fostering of economic opportunity and dissemination of licenses among a wide variety of applicants; recovery for the public of a portion of the value of the radio spectrum; and efficient and intensive use of the spectrum.

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November 10, 1993

Discussion of Proposed Spectrum Auction Processes
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November 10, 1993

I. INTRODUCTION.

The Federal Communications Commission has issued proposed auction procedures defining the mechanism for conducting the upcoming spectrum auctions. This proceeding is one of the most important of a new generation of applications of auctions in public policy. The use of competitive bidding to allocate a substantial natural resource -- electromagnetic spectrum -- promises significant improvements in the efficient allocation and use of this resource. As a longtime student of auction design, I have been asked by the Cellular Telecommunications Industry Association to provide a paper to aid the FCC in constructing appropriate auction rules.

There are numerous different kinds of auctions, which differ on several dimensions. A simple legislative admonition to adopt auctions as an allocation device is a far cry from the detailed construction of rules and processes required for the successful conduct of an actual auction. The FCC has indeed made specific recommendations as to how the auctions are to be conducted. First, it proposes that the basic auction process be an "English" oral auction. Second, it proposes that a *limited* form of a combinatorial auction be created in the following way: After English auctions are conducted for blocks representing a given spectrum in small geographic areas, a sealed bid auction will be held for a single license covering all the geographic areas as a unified whole. If the sum of the winning bids in the individual-blocks auctions exceeds the single winning bid from the sealed bid auction on the combined areas, then the blocks will be sold disaggregated. If, on the other hand, the single winning bid from the combined-areas auction is greater, then the blocks will be awarded aggregated to that one bidder. The FCC requests comment on a Final and Best round allowing the winners in the disaggregated auctions to attempt to reclaim their awards by raising their bids.

The purpose of this paper is to evaluate a few of the key components of the FCC proposal. Specifically, we will address 1) the choice of the English auction as the basic auction type; and 2) the proposal for a limited combinatorial auction. Section II discusses the English auction, and Section III addresses issues relating to the limited combinatorial auction. This paper concludes that: 1) the FCC's proposals regarding the use of English auctions and limited combinatorial bidding are generally sound, both in terms of auction theory and in addressing the practical problems of implementation; and 2) there are significant theoretical problems with a "final and best" mechanism, suggesting that an alternative approach is warranted.

II. THE CHOICE OF THE ENGLISH AUCTION

We limit ourselves to auctions in which a single unit is to be sold at that auction. (This may sound strange given the existence of multiple spectrum blocks. However, recall that we are dealing with auctions in which only a single unit will be awarded *at any one auction*. If there are five auctions selling one spectrum block each, then each auction is still a single unit auction. If all geographic blocks were to be combined into a single national license, then it would still be the case that only one item was being sold at the auction). In a world in which there is only one item for sale at a specific auction, there are four traditional types of auctions:

English (oral) auction

Dutch (oral) auction

First price (sealed bid) auction

Second price (sealed bid) auction.[1]

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[1] The English auction is the traditional ascending price, open outcry auction associated with such items as antiques and art. Bidding continues until no bidder is willing to go higher. The winning bidder pays his own bid. Most Americans are familiar with the English auction from some

(continued...)

Extensively discussed in auction theory and tested in laboratory experiments (one of the most common and reliable empirical methods for evaluating the performance of auctions), a great deal is either known or predicted about these auctions

One can make the following predictions, based upon auction theory, about the performance of the English auction. (All of the discussion below assumes the "independent private values" assumption, which essentially asserts that the values which two different bidders place on the item at auction are not known to one another nor do the values depend on one another).[2]

1) Efficiency. English auctions are predicted to be efficient in that they award the item at auction to the bidder who values it the most. This can be seen fairly simply in the operation of the auction: the bidder who values the auctioned object the most will not sit idly by and allow someone else to win. He will raise the bidding just enough to put all the other bidders out of the auction.

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[1](...continued)
source. Governments have experience with English auctions in such areas as disposal of surplus property.

A Dutch auction is one in which a clock, representing price, starts at a high level and ticks down until the first bidder yells "mine." The winning bidder pays the price on the clock at the point she stopped it.

In a sealed bid auction, each bidder writes a bid on a piece of paper, and submits it to the auctioneer. The bids are opened, and the unit at auction goes to the highest bidder. In the first price auction, the winner pays his own bid. In the second price auction, the winner pays the second highest bid. Sealed bid auctions are commonly used in procurement (although there, as an auction to buy rather than sell, the low bidder wins) and offshore oil leasing. Virtually all of these are of the first price type.

[2] The primary variation on the independent private values assumption which could be of interest here is the so-called "affiliated values" model. This occurs in situations such as when one bidder's valuation on the item depends in some way upon how other bidders value the item. This information cannot be transmitted in a sealed bid auction, but it can be and is transmitted in an English auction. This real-time information sharing tends to increase the expected revenue from an English auction (see McAfee and McMillan [1987]).

2) Approximate demand revelation. An auction is said to be "demand revealing" if it leads the bidders to "reveal" to the auction their true valuations of the item at auction. An example of an auction which is *not* demand revealing is the first price, sealed-bid auction. There bidders will shave their bids below their true valuation of the object.

The English auction is "approximately" demand revealing in that it leads all but one of the bidders to reveal to the auction their true value. The one exception to demand revelation in the English auction is the winning bidder. Again, this makes sense. The English auction stops when the winning bidder just surpasses the desire of any other bidder to make a bid. That final bid, the winning bid, may be well below the winning bidder's actual value.

3) Revenue. The revenue-generating properties of auctions are notoriously difficult to generalize. In absolute terms, the revenue predictions of the English auction are straightforward. The bidding ascends just until the person with the second highest value drops out. Therefore, the English auction can be said to generate a winning bid that is (approximately) the value of the second highest value among all the bidders. This statement does *not* tell how the English auction compares, on average, against the other three common single unit auctions. As mentioned above, these comparisons are complicated and dependent upon several technical assumptions about such things as the risk aversion of the bidders. However, in one obvious benchmark case in which either i) all bidders are expected-profit maximizing firms, or ii) all bidders are risk-neutral individuals, *all four* of the basic single unit auctions generate, on average, the same revenue.

Through the process of laboratory experimental economics, these theoretical properties of English auctions have been thoroughly tested The most well known of this testing is the research of Coppinger, Smith, and Titus [1980]. They found very clear results. First, the English auctions were found to be very efficient: more efficient than Dutch, first-price, or second-price auctions. Second, they found that the English auction "requires the least bidder sophistication."

Third, they found that prices in the English auction were almost exactly as predicted, just slightly above the next to highest valuation (which would be the competitive price in this context).

In light of all of this, the proposal by the FCC to adopt the English auction as its basic mechanism seems to be sound. In addition to the desirable efficiency, demand revelation, and revenue properties discussed above, the English auction has other implementation advantages. It is familiar and easy to understand. No bidder should be scared away by the prospect of participating in an English auction. It is highly unlikely that the English auction will behave in some unexpected, "surprising" sense. The more innovative part of the FCC's proposals is the limited combinatorial auction. It is that aspect of the proposed auctions to which we now turn.

III. THE LIMITED COMBINATORIAL AUCTION

Before discussing the FCC's limited combinatorial auction, it will be useful to discuss the purposes of combinatorial auctions in general. In doing this, one needs to go back one further step to introduce the concept of combinatorial values. In this section, the analysis of the limited combinatorial auction proceeds in four steps. First, the issue of *combinatorial values* is presented. This discussion is important because the need for combinatorial auctions can only be understood in the context of combinatorial bidder values. Second, the intermediate concept of combinatorial bidding is introduced, followed by a discussion of full-blown combinatorial auctions. Finally, the FCC's specific proposal is evaluated in light of the prior discussion.

A. Combinatorial Values.

We often think of auctions as a series of individual allocation processes involving single items, either because literally only one item is at auction (i.e., a bid opening to build a single building) or because items which may be similar are auctioned in separate lots (paintings,

offshore oil leases, etc.). Even when multiple items are bundled together (e.g., wine auctions) we can them think of them as a single item -- the lot.

In the context of these different auction processes for different items, it is often still common to think of each bidder as having a well defined "value" (known only to himself) for the item. This value could be the maximum the collector would be willing to pay for a painting or the minimum amount a construction firm could charge and still profitably build a building. However, this is not the only possible description of bidder values. Another approach recognizes that how much someone values one object may depend upon what other objects they do or do not possess. Thus, an airline's valuation of an airport 'slot" in Washington may depend upon whether or not it has a similar slot in Chicago (Grether, Isaac, and Plott [1989]). An art collector may value a matched pair of famous paintings more than the sum of how she would value either of them separately. An oil company may value a particular offshore oil tract perhaps more or less depending upon whether it has obtained an adjacent tract.

Obviously, from these examples, it can be seen that combinatorial values can exist outside of auctions but they certainly can also exist in the context of auctions. One famous public policy example of combinatorial values is that of airport "slots" (roughly take off and landing rights or gatespace rights) described above. The problem was that neither under the existing committee system for allocating airport slots nor under an airport-by-airport auction process could carriers express their combinatorial values inside the route system. Grether, Isaac, and Plott suggested dealing with the problem by an open-book exchange market following the auctions (an aftermarket). Later, Bulfin, Rassenti, and Smith [1982] proposed another solution, relying upon a different type of auction to better express combinatorial values. We will return to their idea in the next section.

B. Combinatorial Bidding.

In ordinary auctions, the problem of combinatorial values is handled in an *ad hoc* manner. Sellers (buyers in a procurement auction) will sometimes attempt to anticipate in advance obvious combinatorial valuation problems in defining the product for sale. (An obvious but meaningful example is an automobile auction; the seller seldom auctions off the tires first, then the battery, then the seats, and so forth). In addition, attempts to maximize combinatorial value take place in aftermarkets, through informal decentralized bundling and unbundling of commodities. As discussed above, Grether, Isaac, and Plott proposed making this rebundling slightly more formal through an official "open book" process. But the key point here is that, at the level of the auction itself, our standard auctions simply ignore combinatorics. Each bidder submits an unconditional bid for whatever unit is bid on. If a bidder purchases two items, whether in the same multiple unit auction or in two different auctions, that bidder is never able to convey to the system his combinatorial values When bidders cannot fully convey their combinatoric values to the market, there is an increased danger that the first round will not be fully efficient. And, if all of the gains from exchange are not captured in the market, then the likelihood is increased of an immediate aftermarket whose sole purpose is to capture the gains from exchange missed by the first round.

In the early 1980s, the non-combinatorial view of auctions began to change. In a paper by Forsythe and Isaac [1982], the authors examined properties of both multiple unit and multiple object auctions, building upon the seminal auction work of Vickrey [1961]. In this investigation, the authors developed the idea of *combinatorial bidding*. They used a stamp auction as their example. Consider an auction for two rare stamps, currently joined together. Should the seller sell them separately or joined together? Let's suppose that, under ordinary circumstances, the seller is using a first-price sealed-bid auction. Then she has to make a guess, in advance, how the combinatorial values are going to go. If she splits them apart, and the greatest value was

together, then this lost value might be guessed-at only after it is too late. If the stamps are left together but the greatest value is apart, then the seller is likely to see aftermarket resales with profits flowing not to her but to the first purchaser.

How would combinatorial bidding operate differently? In combinatorial auctions, each bidder is invited to submit a bid on each of the possible combinations of the two stamps. In other words, each bidder submits (in this example) three bids:

$$b_r,\ b_l,\ b$$

that is, a bid for the right stamp *only*, a bid for the left stamp *only*, and a bid for the two stamps together. How are the stamps sold? The seller (today aided by a computer program) would go through all of the possible ways of selling the two stamps, and choose the combination that yielded the greatest total bids. The auction **itself** would solve for the optimal way of bundling the stamps.

At virtually the same time that the Forsythe and Isaac paper appeared, Rassenti, Smith, and Bulfin published a paper on combinatorial auctions using essentially the same description of combinatorial bidding described here. Interestingly, the public policy problem motivating their interest in combinatorial auctions was the airport slot problem discussed above. They proposed using a combinatorial auction, and conducted economics experiments that showed that their version of a combinatorial auction was more efficient than the open-book process of Grether, Isaac, and, Plott.

Regardless of which manifestation of combinatorial bidding one considers, there are some important common attributes which should be emphasized. Combinatorial bidding allows bidders to express their combinatorial values; bids can now more accurately reflect the valuation of different combinations of the goods at auction (although the type of bidding must still be considered; this is addressed below). The *market* becomes the mechanism for determining the combination of goods. As the Rassenti, et al. auctions demonstrated, this makes it more likely

that exchange efficiencies will be captured in the auction and not delayed until an aftermarket. Another advantage of combinatorial auctions is that bidders can assign values (and hence bids) with greater certainty. Imagine a bidder who really wants only one couch, but has the opportunity to bid in two different, simultaneous, sealed bid couch auctions. If he bids in only one auction he may end up with none, but if he bids in two, he risks winning two. The ability to express combinatorial values effectively eliminates this problem.

It is interesting that, having stumbled upon the idea of combinatorial bidding at such similar time, Forsythe and Isaac and Rassenti, et al. did not propose the *same* combinatorial auction. We turn to the reason for this in the next section.

C. Combinatorial Auctions.

In the previous section we discussed the key insight of *combinatorial bidding*, describing the form that the bids were to take and the altered auction award rule (accept those bid combinations that maximize revealed value). However, these two components do not, in and of themselves, define a complete combinatorial auction. What has not yet been specified is a crucial component of any auction: *what do the winning bidders have to pay*? (Consider, for example, in the world of single unit sealed-bid auctions, the difference between a first-price and second-price payment rule. Or, in the world of homogenous multiple unit auctions -- Treasury auctions -- the discriminative versus uniform price payment rule) A uniformly accepted "best" payment rule for combinatorial auctions has not yet been developed

In combinatorial auctions, one approach might be simply to stick with the discriminative pricing rule: the winning bidders pay what they bid. The advantages are that the rule remains well defined in combinatorial auctions, it is easy to understand, and it would be familiar to most bidders. The disadvantages are those always associated with discriminative bidding. In order to make money, bidders *must* shave their bids below true value. This can lead, in certain circumstances, to possibilities of inefficient allocation of the resource and, possibly, to less than

optimal revenue capture for the seller. (This revenue question is exactly what has been occupying the efforts of the Treasury in its comparison of uniform versus discriminative bidding).

In more traditional auctions, the typical alternative to discriminative bidding has been the family of competitive auctions: second price (single unit) or uniform price (multiple unit) auctions. In a single unit, second price auction, the highest bidder wins the auction *but pays the highest losing bid* (the second price). If there are 1,000 units for sale in a uniform price auction, the 1,000 highest bids win, and *they all pay the 1,001st price*. This family of auctions has been shown, in general, to generate more accurate value revelation, and there are *some* environments in which the competitive auctions outperform the discriminative auctions in revenue terms (in others, discriminative auctions do better). There is, unfortunately, a problem in considering a simple competitive rule in combinatorial auctions: the concept of the "highest losing bid" may not exist. Consider the two stamp example again. Suppose that the stamps are awarded to two different bidders. However, after their summed separate bids, the next highest bid for the two stamps is a combination bid of a single individual. What should each of the two winning bidders pay? The rule "pay the highest losing bid" is inadequate in this context.

There have been a couple of different approaches to solving this problem of the poorly defined "highest losing bid" auction. Forsythe and Isaac decided that instead of enshrining the "highest losing bid" aspect of the auction that they would concentrate on the issue of demand (value) revelation and return to the roots of the problem as developed in Vickrey and later in Groves (see Green, et al.[1977]). By means of a clever mathematical trick, Forsythe and Isaac were able to derive the Vickrey (demand revealing) version of the combinatorial auction. Despite the success on the demand-revealing front, that auction has two major problems. First, it is difficult to describe (an implementation problem which should not be underestimated). Secondly, there are no "prices" in the usual sense of there being costs associated with individual items. Instead, there is a "charge" or "fee" for each winning bidder. Consider a combinatorial airport